Estimates of Initial Value Decadal Predictability for CCSM3

Part I: North Pacific

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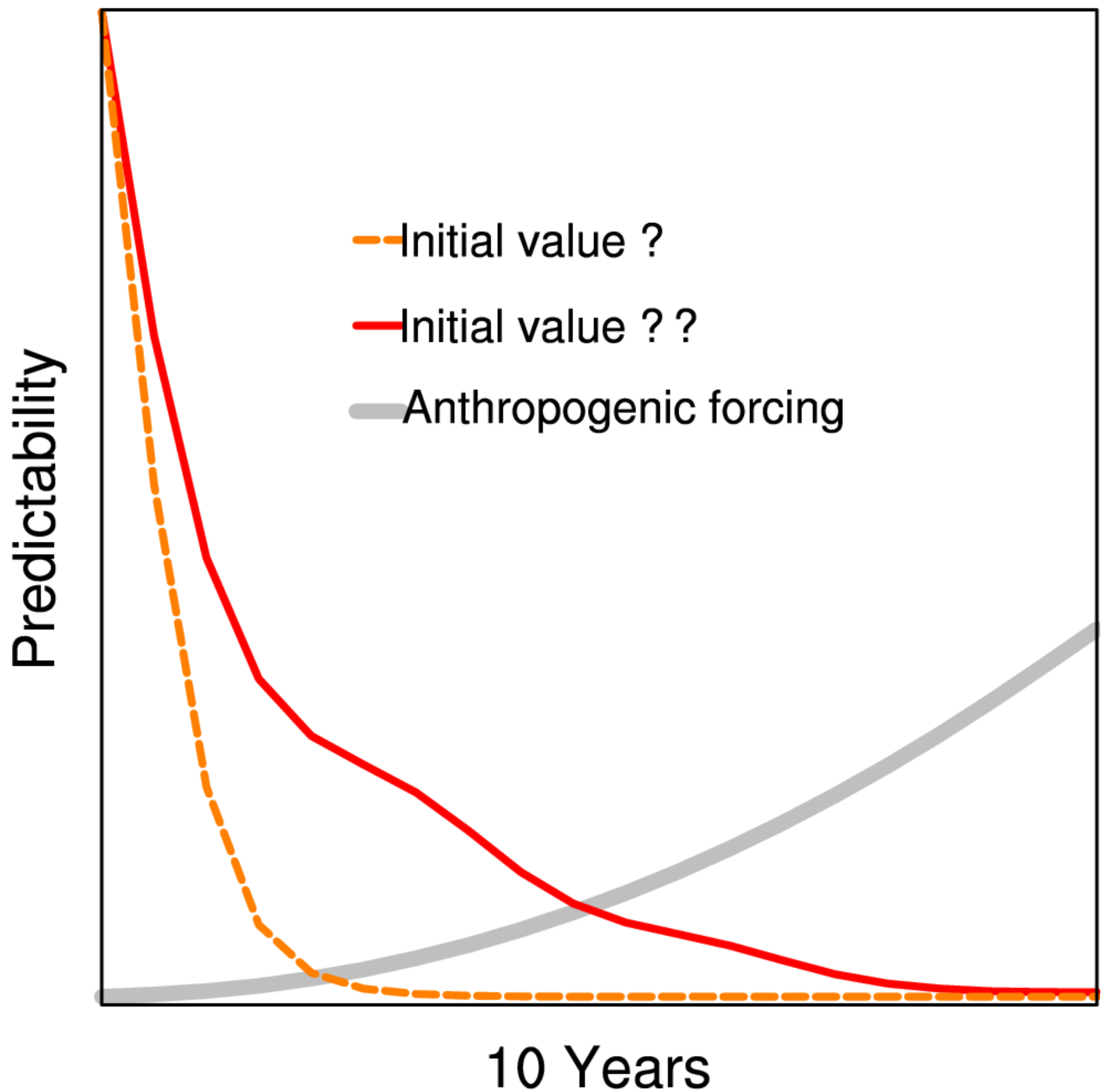
Motivation



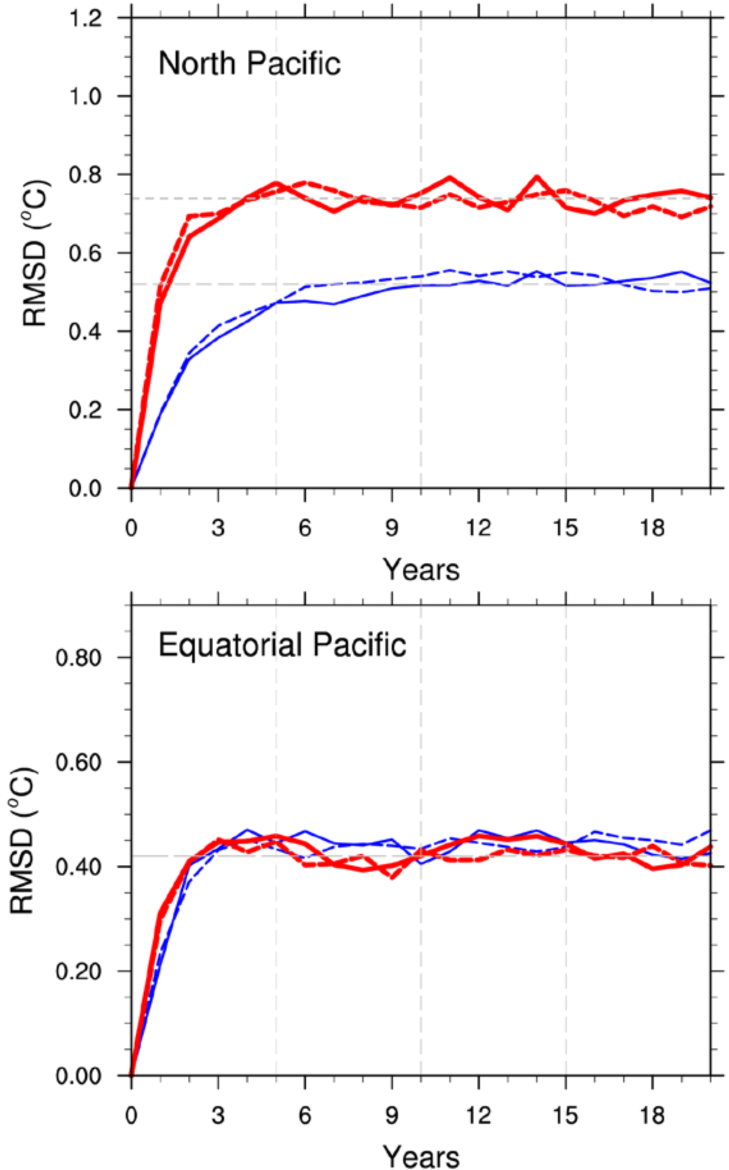
Initial value ?
Initial value ? ?
Anthropogenic forcing
Predictability
10 Years

Experiments

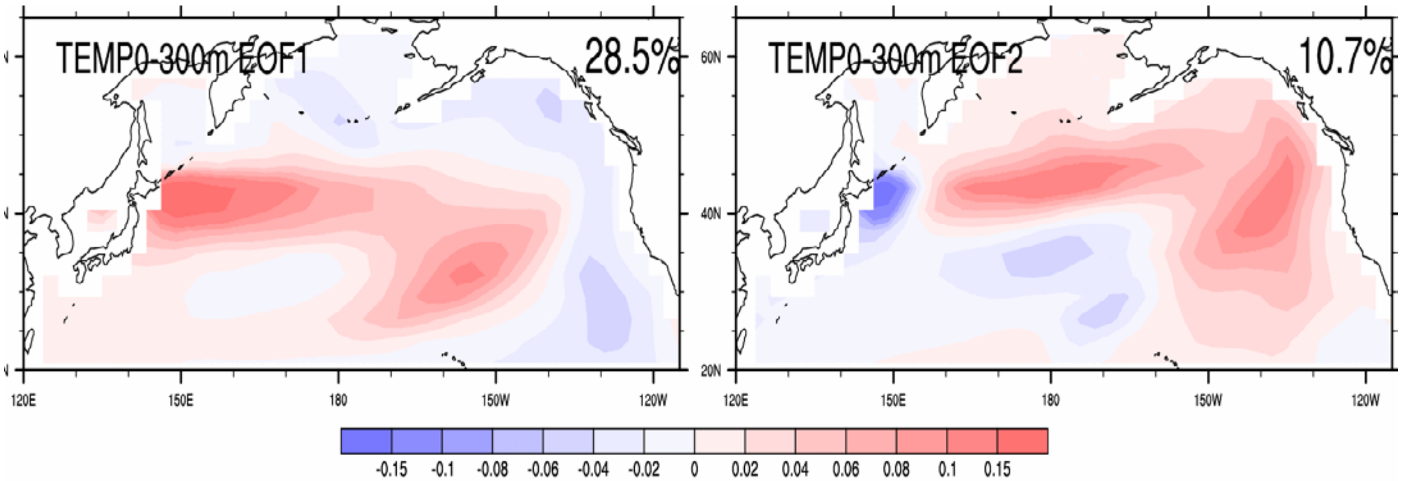
CCSM3 Experiments	Period	External forcing	Initial perturbation	Initial ocean state
Present-day control	0300-0999	control		
Ensemble I (40 members)	2000-2061	SRES A1B	Different atm/ same ocn, ice, lnd	Close to neutral PDO
Ensemble II (40 members)	2008-2028	SRES A1B	Infinitesimal differences in the solar constant	Very warm PDO

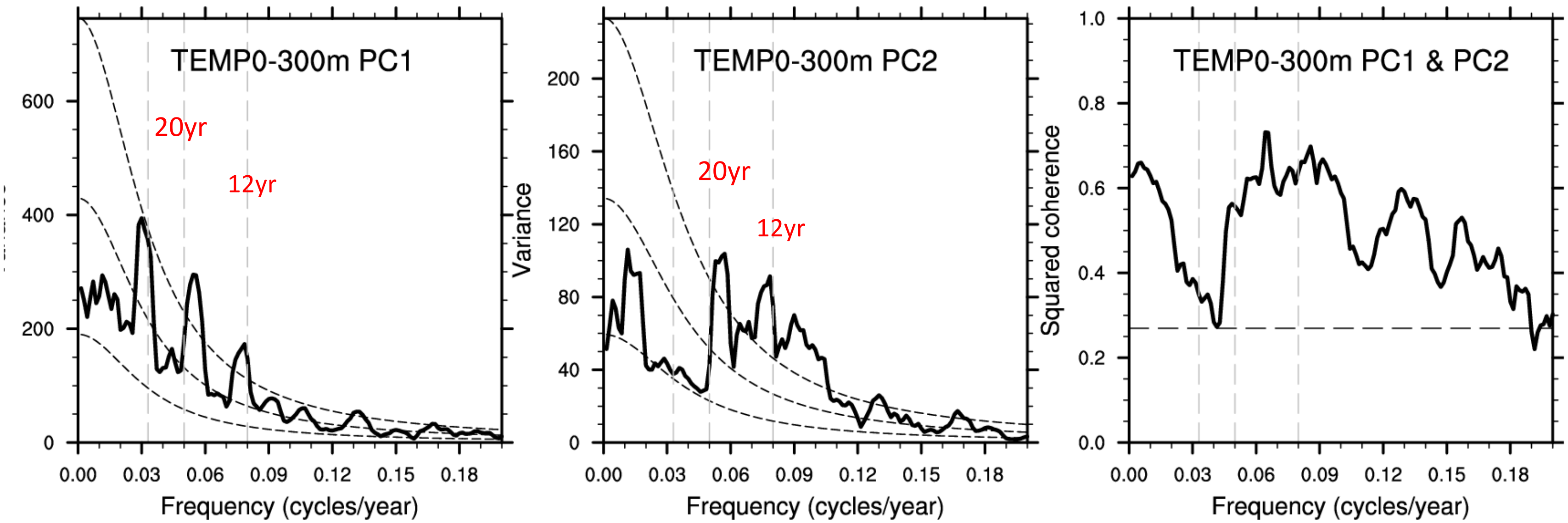
Root Mean Square Difference

in SST and upper 300m temperature



Leading EOF Modes

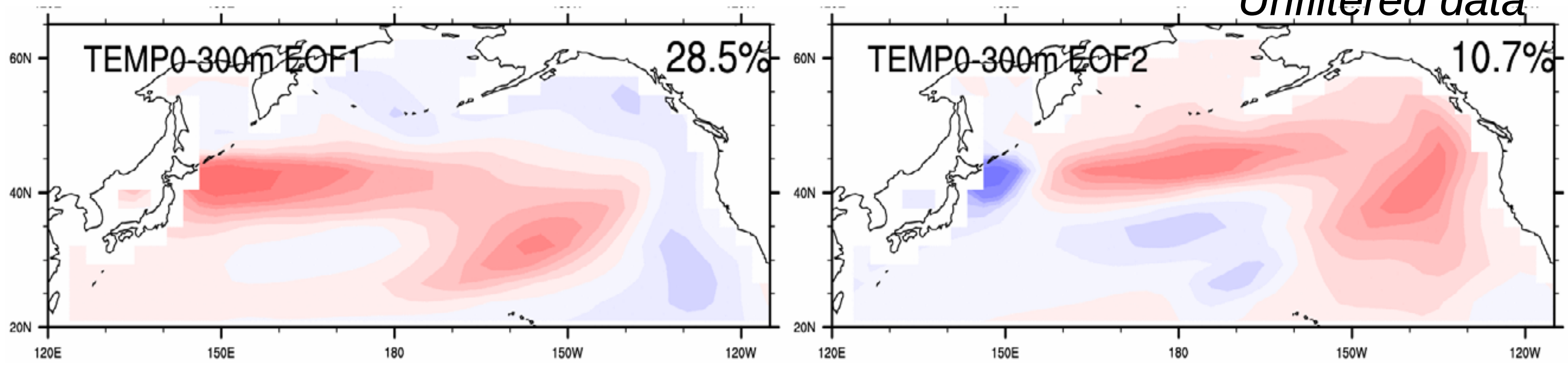




From 700-yr control

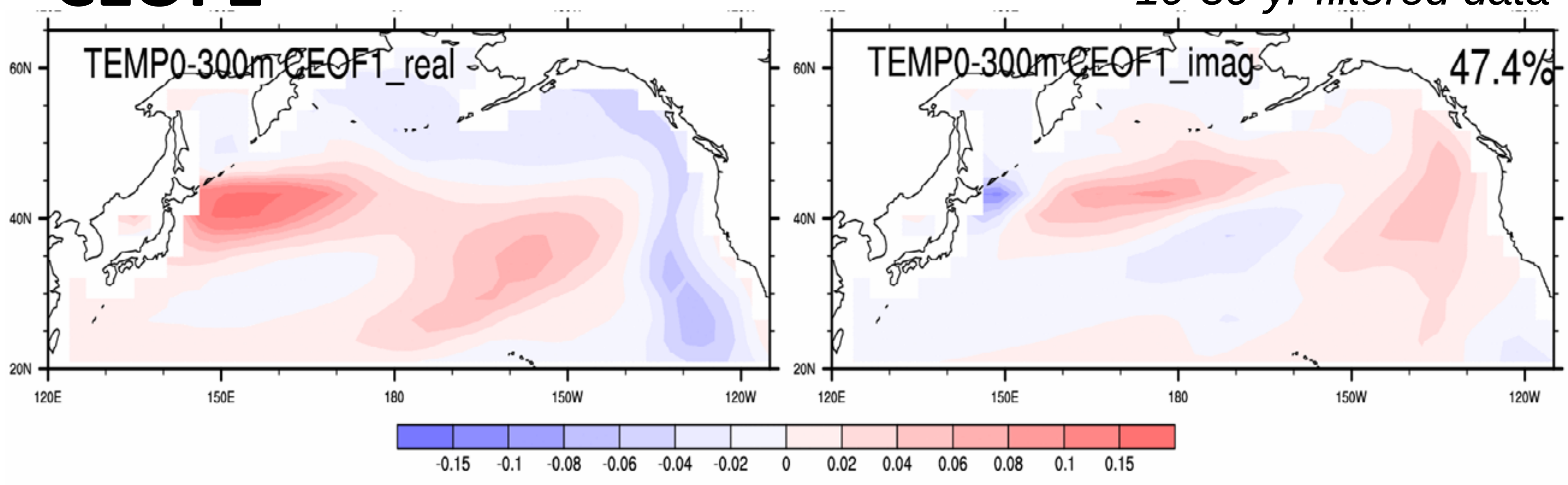
EOF1,2

Unfiltered data

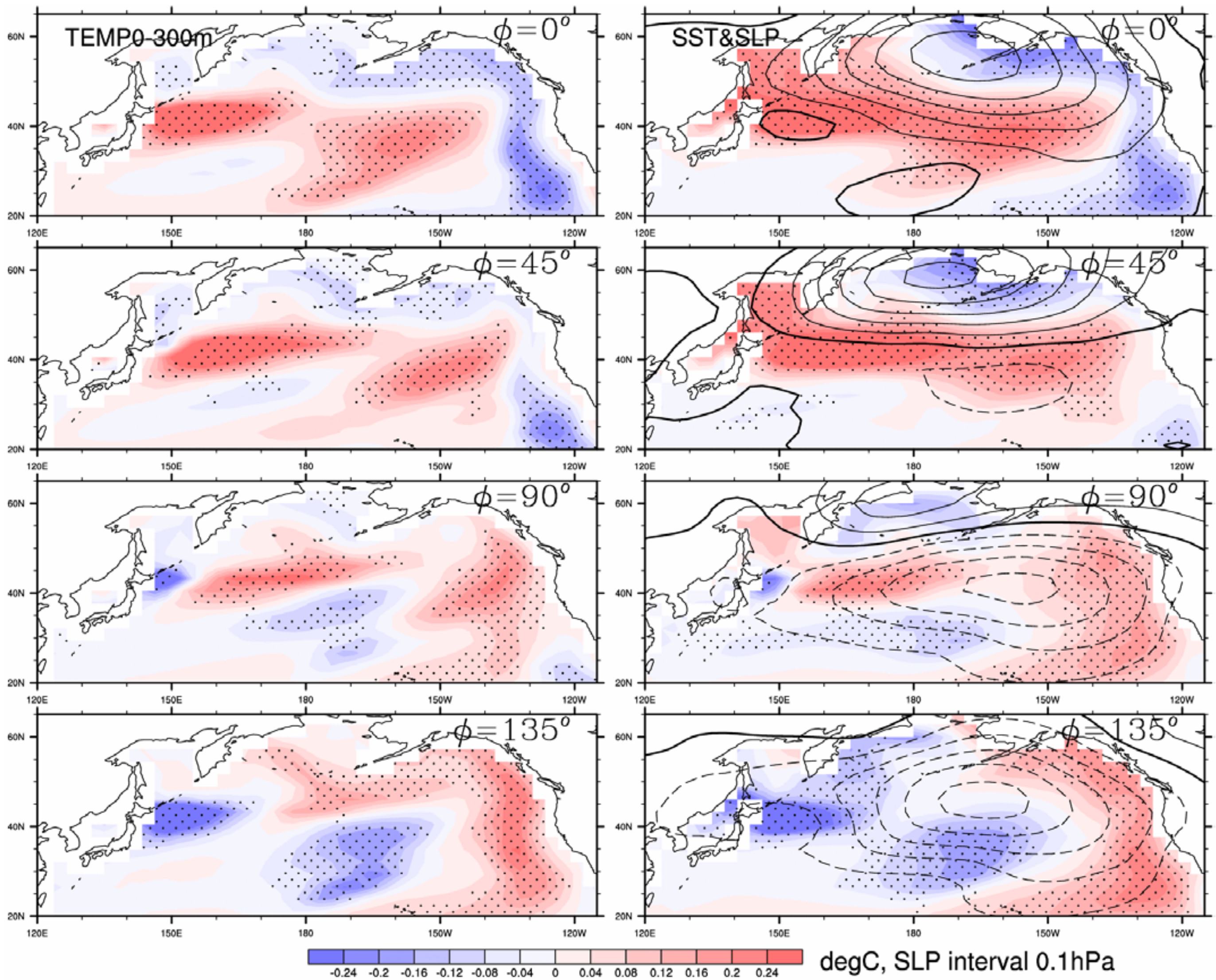


CEOF1

10-30-yr filtered data



Evolution of Subsurface Temperature CEOF1 & SST, SLP

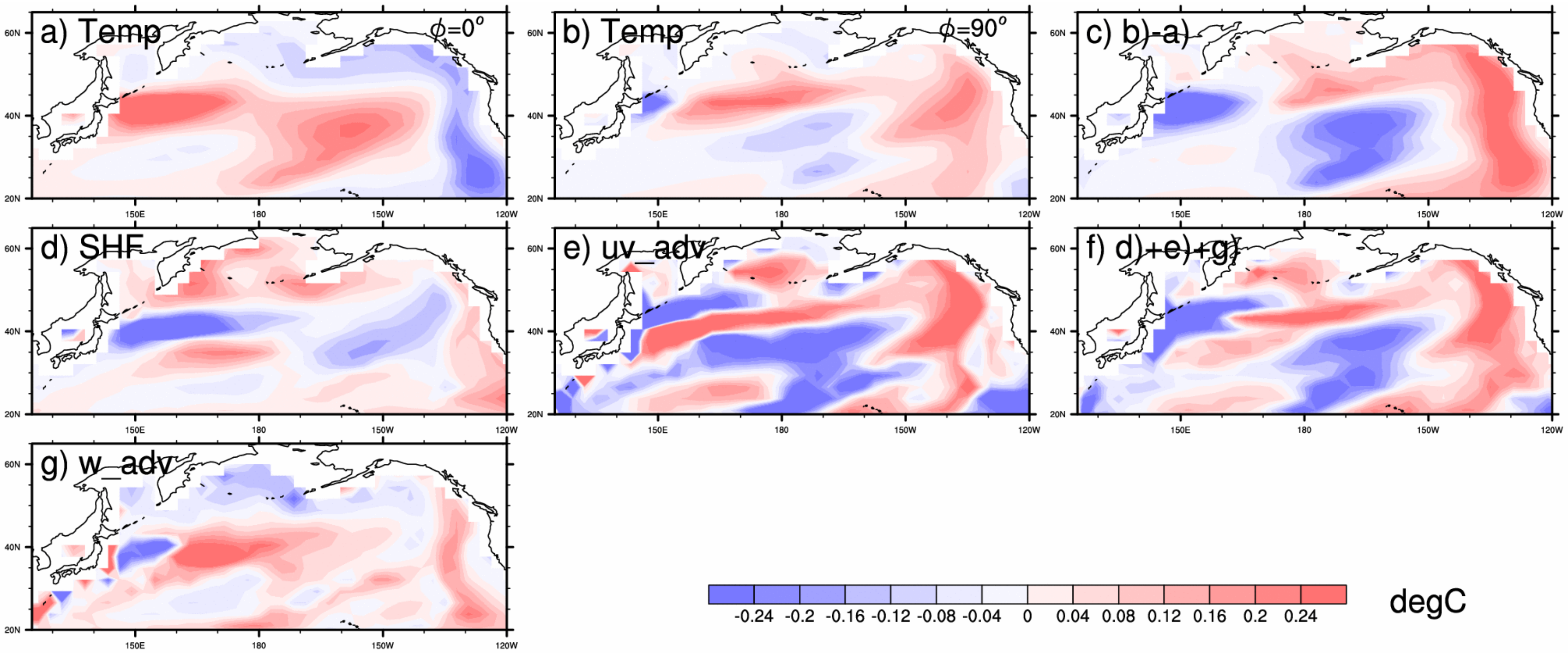


composite based on 10-30-yr filtered data, ~ 60 episodes in 700-yr control

Heat Budget Analysis of CEOF1

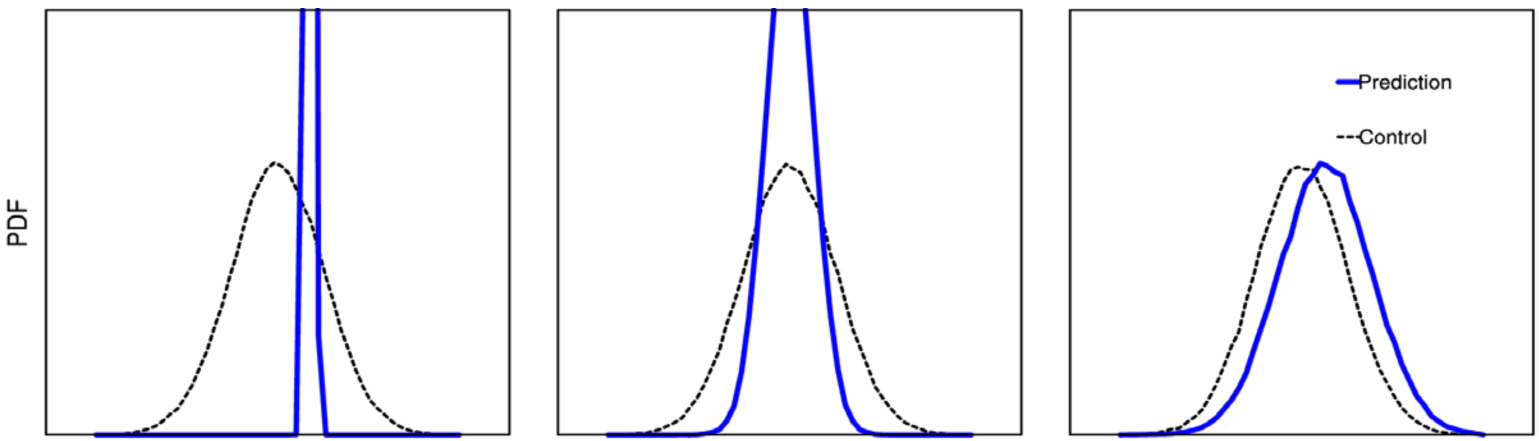
$$\frac{\partial T}{\partial t} = -\omega\frac{\partial T}{\partial z} - \left(u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y}\right) - \frac{Q_{net}}{\rho_0 C_p H}$$

(w_adv) (uv_adv) (SHF)

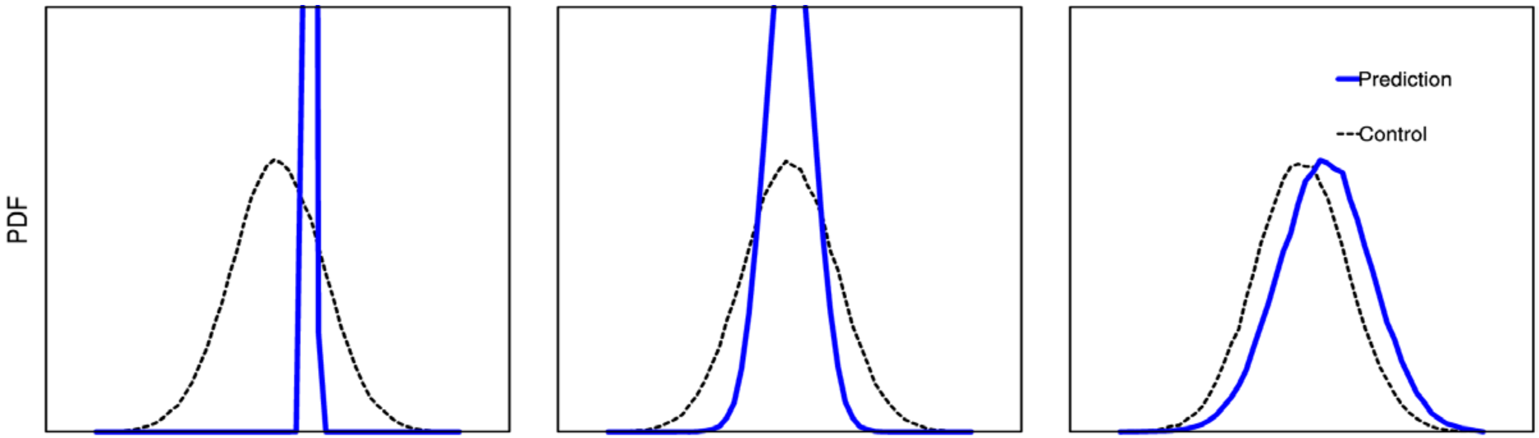


Composite based on 10-30-yr filtered data in 700-yr control

Measure of Predictability



Measure of Predictability: Relative Entropy



Kleeman (2002)

$$R = \sum_i p_i \ln(\frac{p_i}{q_i})$$

p_i: *Prediction,* q_i: *Climatological distribution*

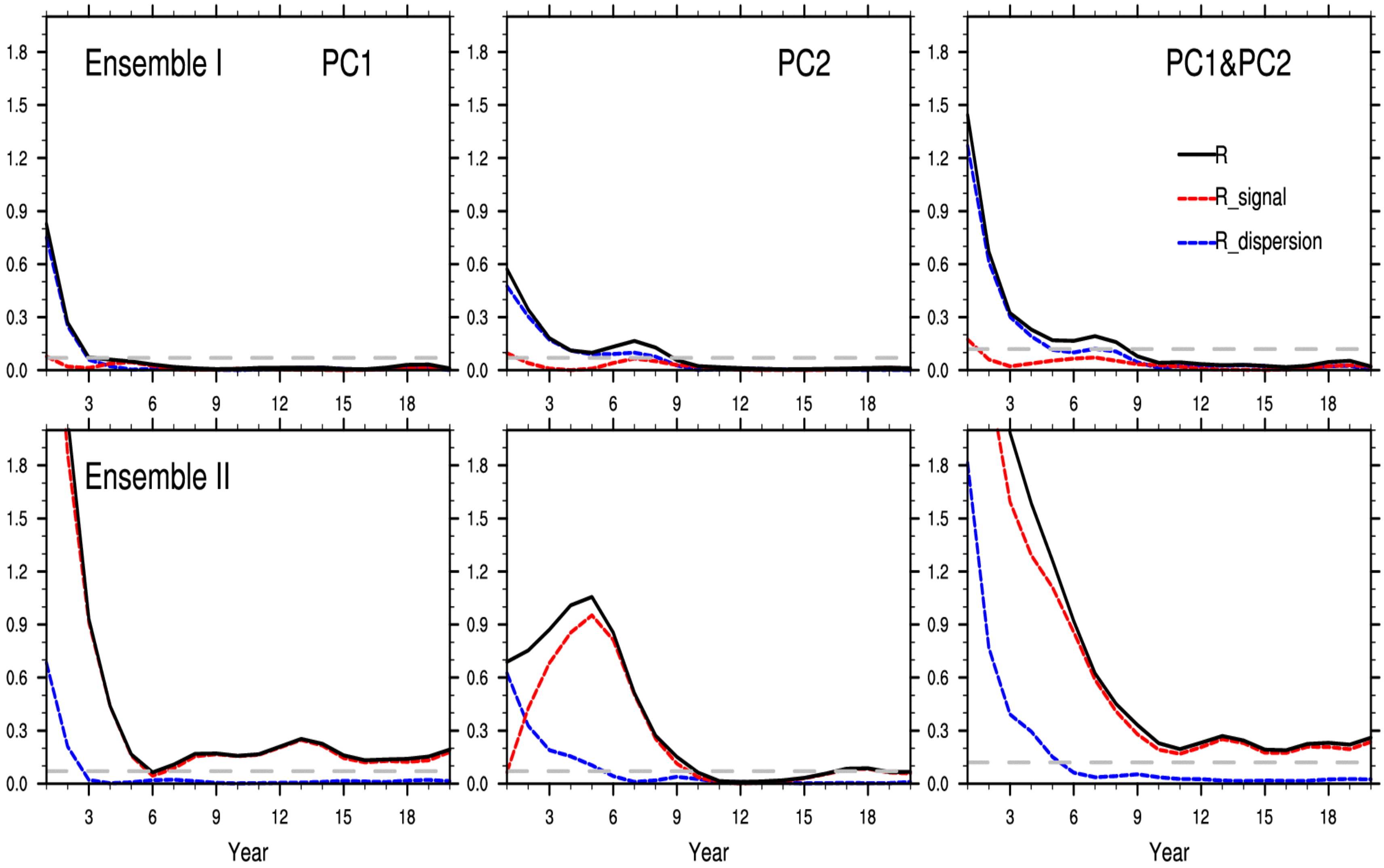
For normal distribution:

$$R_1 = \frac{1}{2}\left[\ln(\frac{\sigma^2_c}{\sigma^2_e}) + \frac{\sigma^2_e}{\sigma^2_c} + \frac{(\mu^e - \mu^c)^2}{\sigma^2_c} - 1\right]$$

$$R_n = \frac{1}{2}\left\{\ln\left[\frac{\det(\sigma^2_c)}{\det(\sigma^2_e)}\right] + tr\left[\sigma^2_e(\sigma^2_c)^{-1}\right] + (\vec{\mu^e} - \vec{\mu^c})^t(\sigma^2_c)^{-1}(\vec{\mu^e} - \vec{\mu^c}) - n\right\}$$

dispersion **signal**

Relative Entropy of the Leading EOF Modes



Predictability in a Linear System from the Control Run

Linear Inverse Model (LIM)

Penland (1989)

$$\frac{d\vec{X}}{dt} = B\vec{X} + \xi$$

$$\vec{X}(t+\tau) = e^{B\tau}\,\vec{X}(t)$$

$$B = \tau_0^{-1}\ln\{C(\tau_0)C(0)^{-1}\}$$

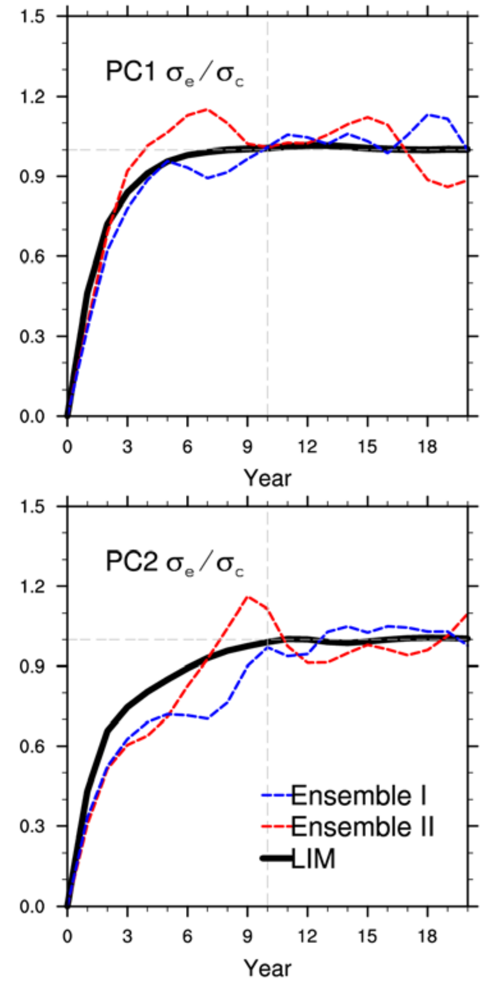
$$C(\tau_0) = \left\langle \vec{X}(t+\tau_0)\vec{X}^T(t) \right\rangle$$

$$C(0) = \left\langle \vec{X}(t)\vec{X}^T(t) \right\rangle$$

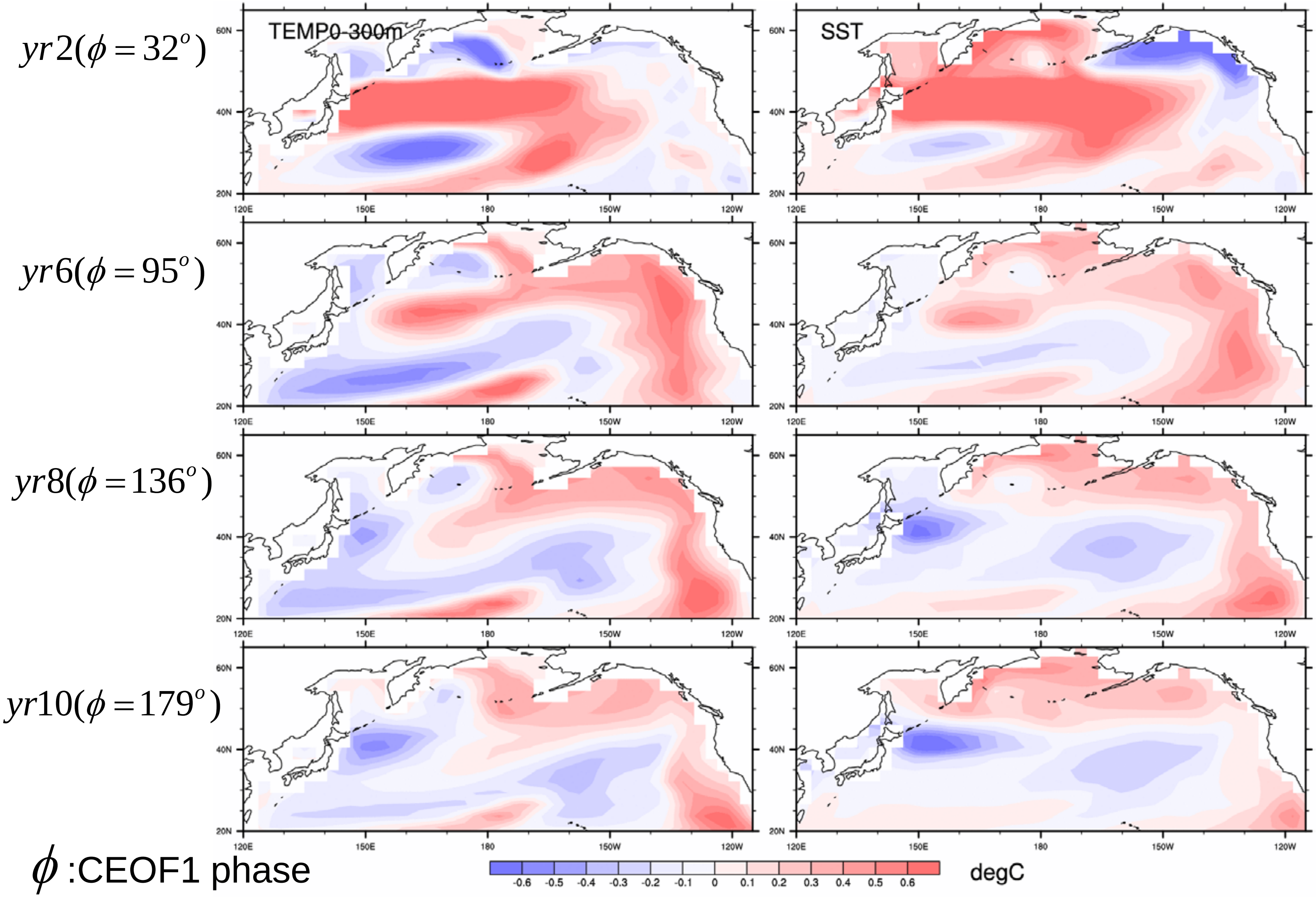
$$G \equiv e^{B\tau}$$

$$\left\langle \xi\xi^T \right\rangle = C(0) - G(\tau)C(0)\,G^T(\tau)$$

PC1 & PC2 error growth rate

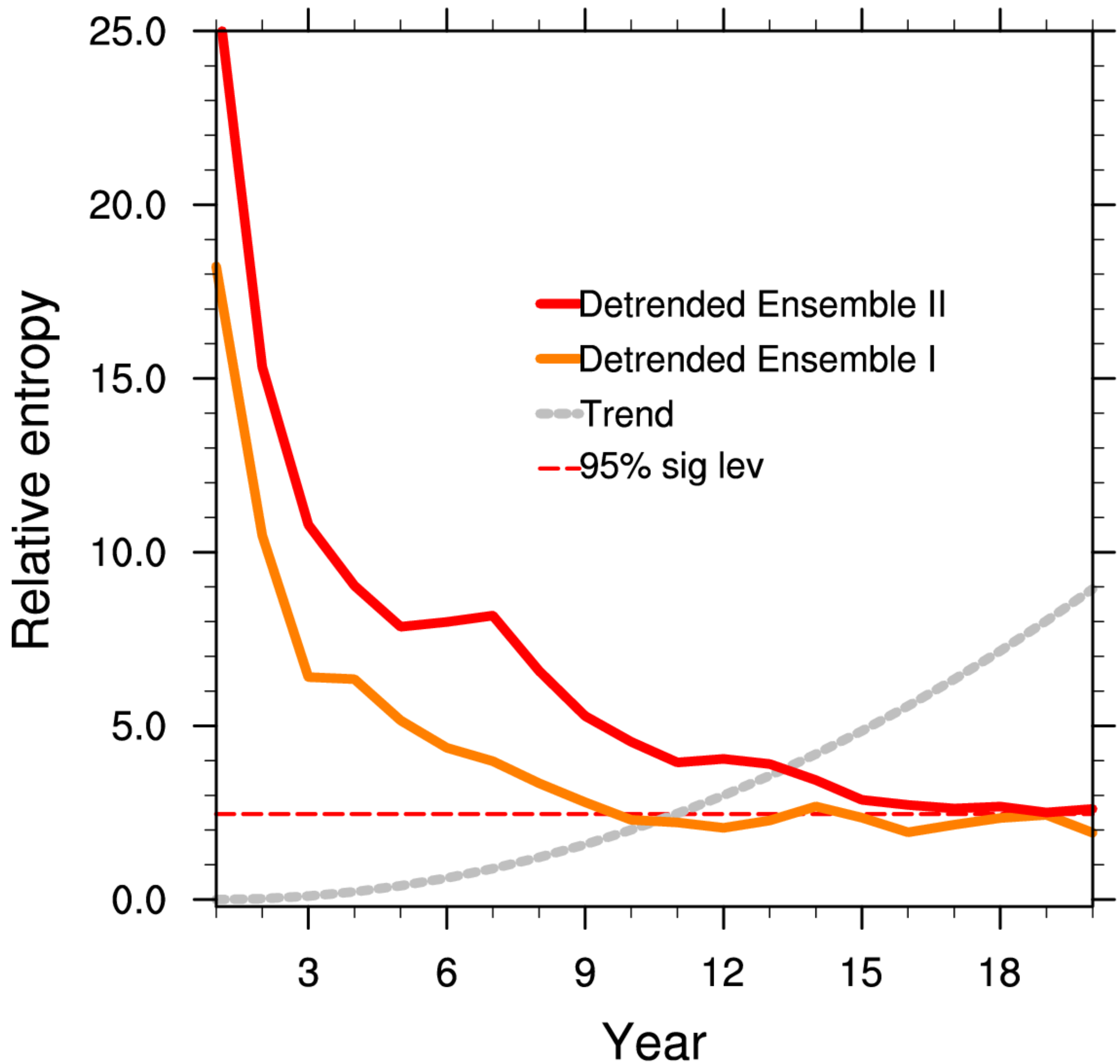


Ensemble II Averaged Detrended Anomalies



ϕ :CEOF1 phase

Relative Entropy of Leading 15 EOFs



Summary

- Initial value predictability of the **EOF1** of North Pacific subsurface temperature is limited to **about 6 years** in CCSM3.

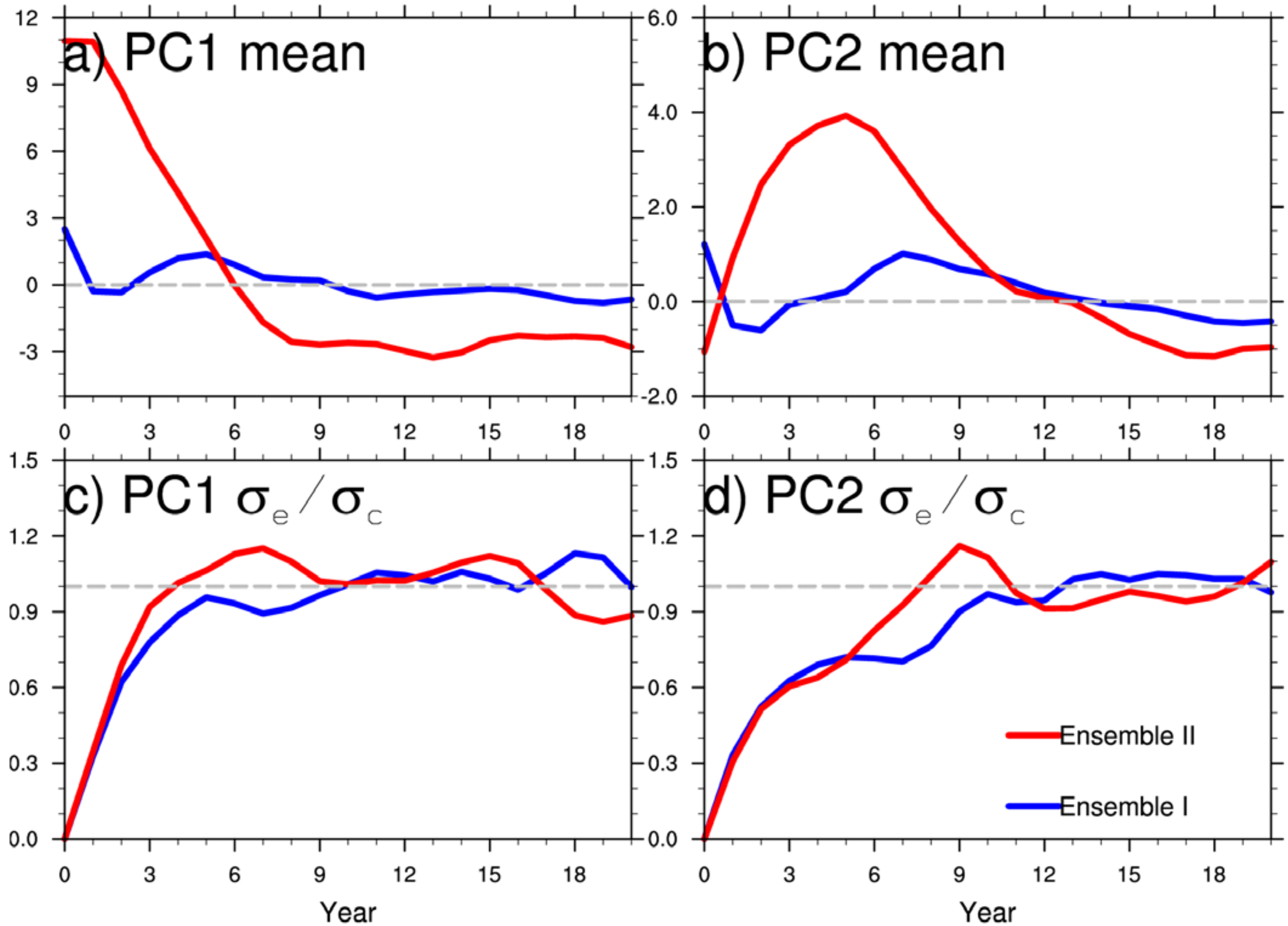
- **Enhanced predictability** resides in the **evolution from the EOF1 to EOF2**; the latter is caused by horizontal advection of EOF1. Combining the two EOFs, the leading propagating mode is predictable for 8 and 10 years in the two ensembles respectively.

- The leading propagating mode has **a similar dispersion rate** in the two ensembles. **Enhanced predictability** in Ensemble II results from **a much stronger initial signal** in EOF1.

- The **dispersion rate** of the leading propagating mode seems to be **a general property of the system** because it agrees with the LIM estimates based on the control run.

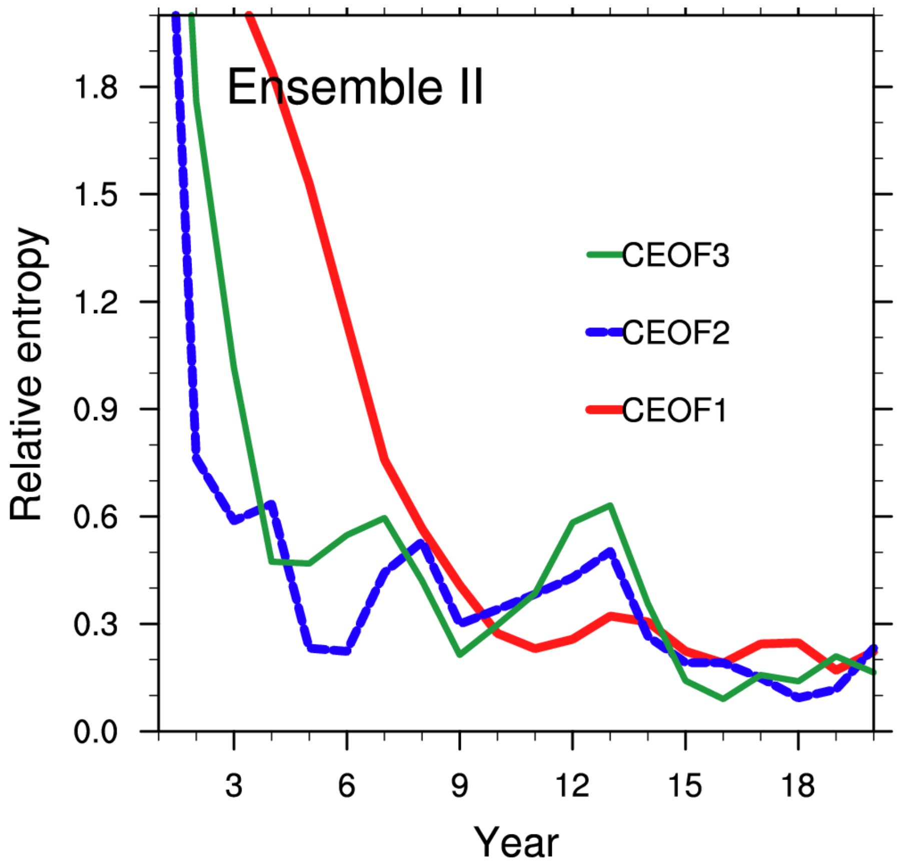
- **On average**, the North Pacific subsurface temperature **loses initial value predictability in 10-15 years** in the two ensembles. **After a decade**, **predictability of the second kind** due to anthropogenic forcing becomes significant.

Ensemble Mean & Spread of PC1, PC2



σ_e : ensemble stddev σ_c : control stddev

Relative Entropy of Leading CEOFs



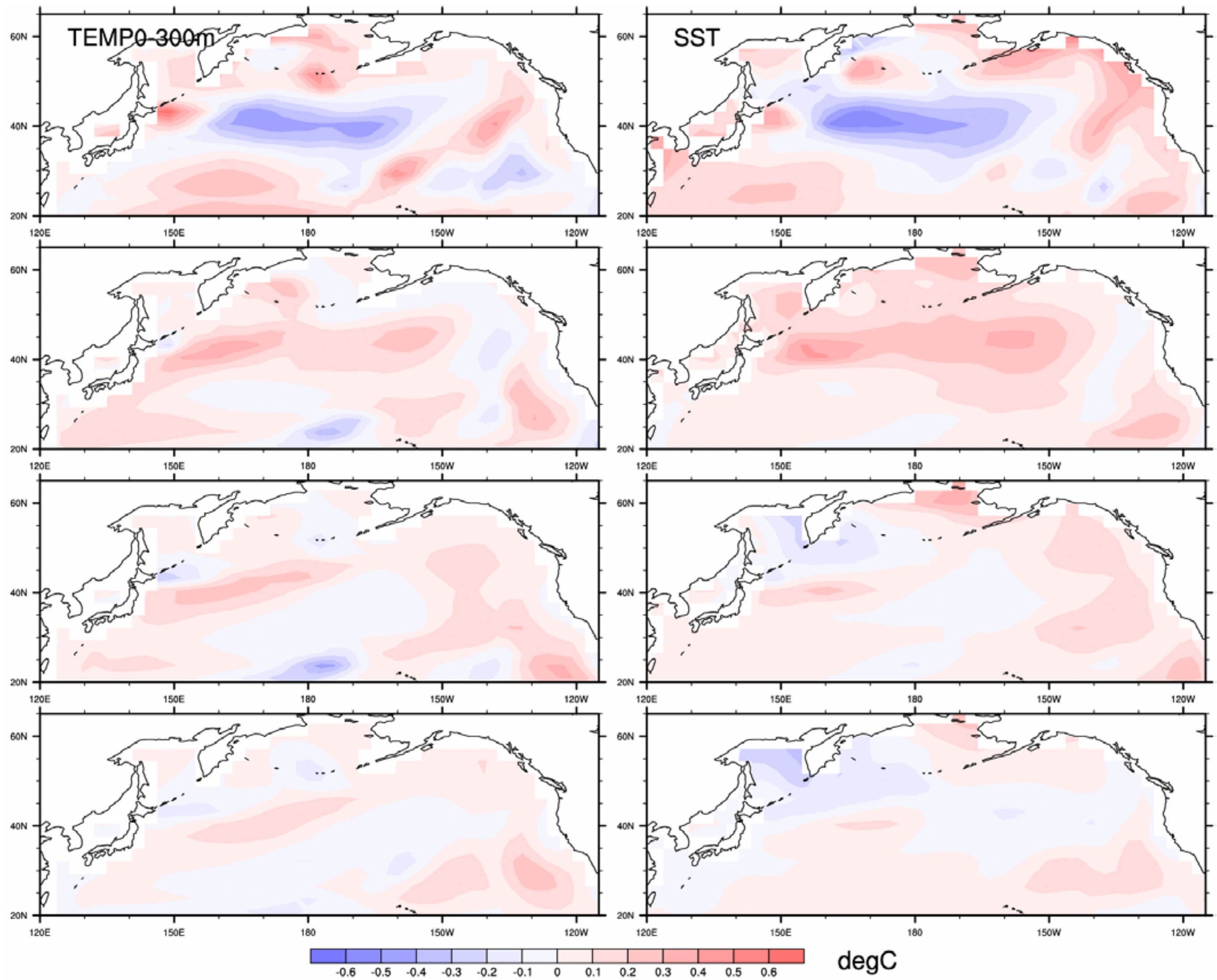
Ensemble I Averaged Detrended Anomalies

$yr2(\phi = 32^o)$

$yr6(\phi = 95^o)$

$yr8(\phi = 136^o)$

$yr10(\phi = 179^o)$



ϕ :CEOF1 phase